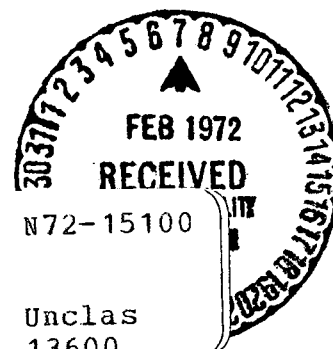


BIOTECHNICAL LIFE SUPPORT SYSTEM FOR SPACE OBJECTS

All-Union Scientific Research Biotechnical Institute

Translation of "Biotechnicheskaya Sistema  
Zhizneobespecheniya Kosmicheskikh Ob'yektov",  
USSR Academy of Sciences, Moscow, "Nauka"  
Press, 1970, 11 pages.

(NASA-TT-F-14102) BIOTECHNICAL LIFE  
SUPPORT SYSTEM FOR SPACE OBJECTS (Techtran  
Corp.) Jan. 1971 14 p CSCL 06K



Unclas  
G3/05 13600

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D. C. 20546 JANUARY 1971

## BIOTECHNICAL LIFE-SUPPORT SYSTEM FOR SPACE OBJECTS

All Union Scientific Research Biotechnical Institute

ABSTRACT. The article describes a mockup of a biotechnical life-support system for space objects. It includes a sun simulator for growing plants, gas exchange apparatus, hothouse, chicken cultivator, algae cultivator, heat and moisture regulating system, lighting system, waste product collection system, bathroom with shower, and other components. Under present conditions, necessary supplies for space flights of up to 3 years weigh tens of tons. The system would weigh considerably less. Its principle is regeneration of substances necessary for maintenance of life at an adequate level for carrying out flight operations.

The prolonged stay of man in conditions of space flight makes it necessary /2\* to provide the elements important for his vital functions, especially water, oxygen and nourishing food.

Life-support systems for short-term flights include principally reserves of drinking water, food products and highly active substances which absorb carbon dioxide and air moisture and which give off oxygen. The weight of these reserves increases proportionally to the functioning life of a space object and the number of crew members. For a prolonged flight (up to 3 years) the weight of such a system is figured in tens of tons. Therefore, in this situation, a system is needed in which regeneration of substances required by man from products of human vital activity is possible.

The idea of creating such a life-support system was first mentioned by K. E. Tsiolkovskiy. He proposed that possible components of a system which would regenerate oxygen and food would be green plants which use solar energy and products which are eliminated by man, similar to the way this is done in

---

\*Numbers in the margin indicate pagination in the foreign text.

nature. However, the commonly known system of cycling of substances in nature, can be used only in a general sense for describing processes which go on in life-support systems. The creation of highly effective systems on the basis of physiological-biochemical reactions of biological objects (for example, photosynthesis or transpiration of plants) is a serious biological-technical problem.

The crops most widely studied as components of biotechnical life-support systems are unicellular algae and certain higher plants. They were first examined as extremely active participants in the process of regeneration of air (absorption of carbon dioxide, of certain toxic gas-like mixtures and elimination of oxygen) and the regeneration of water from urine and certain other waste products of the life-support system; secondly, principally as a source of fresh plant food products, which would permit maintenance of the psychological-physiological activity of man at a high level under conditions of space flight.

The volume of separate biological units in the life-support system can vary depending on the type of life-support system, the functioning time, peculiarities of providing light energy and so on.

For determining the optimum composition of a set of biotechnical units and the conditions of their operation an experimental mockup of a life-support system was created (Figure 1), which is designed to supply the needs of three men of water, oxygen and fresh plant products during an unlimited period of time.

The principal regenerating units in this system are an algae cultivator and hothouse.

Carbon dioxide from the crew compartment is supplied directly to the algae cultivator and, during the daylight period of higher plants (14 hours a day), to the hothouse. A corresponding amount of oxygen eliminated by the plants enters the gaseous mixture which circulates in the units. The gas mixture, enriched by oxygen, is dried in condensers in the heat and moisture control system and is sent to the crew compartment. /4

/3,4,5

FOLDOUT FRAME 2 C

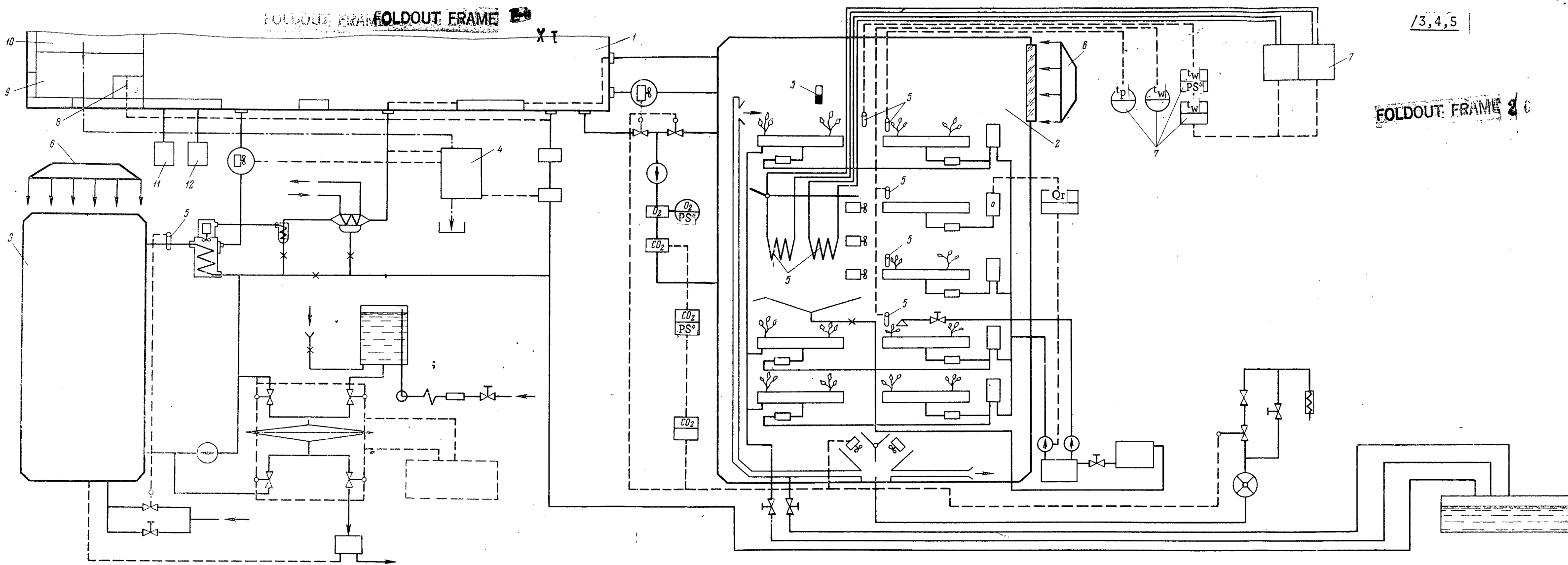


Figure 1. Functional Circuit of A Biotechnical Life-Support System. 1- Cabin for the crew; 2- Hothouse; 3- Algae cultivator; 4- Chicken cultivator; 5-Heat and moisture regulating system; 6- Lighting system; 7- Unit for automatic control and regulation of the life-support system parameters; 8- Unit for collection of human life activity products; 9- Sanitary compartment with shower; 10- Kitchen and food reserve section; 11- Communication panel; 12- Equipment for medical control of the crew's health. Key: \*- expansion unknown;  $t_p$  - temperature of plants;  $t_w$  - temperature of water.

Purifying the air of toxic gas-like impurities which accumulate in the system is achieved by an absorption-filter placed in the cabin. Certain gas-like substances (carbon monoxide, hydrocarbons and so on) are absorbed in the algae cultivator.

Regeneration of water in the system is realized from urine, cabin air /5  
moisture condensate and the common water supply. All these waste products are collected in a unit for preliminary treatment, and then they are sent to the algae cultivator where certain organic and mineral impurities, which are absorbed by the algae-bacterial cenosis of the cultivator, are removed from them. An equal amount of liquid is removed from the algae cultivator in the form of a condensate of air moisture, which emerges from the gas exchange apparatus of the cultivator, and is sent to the unit where a nutrient solution is produced.

The water undergoes final purification with the aid of plant transpiration in the hothouse. As the results of an experiment showed, the transpired water, according to its chemical composition, is practically distilled water. Only part of the total amount of the transpired water is removed to satisfy the needs of the crew. The water for drinking and food preparation is pre-saturated with the necessary salts.

For sanitary and hygienic needs the water is supplied directly from the transpired water storage tank.

Production of plant food products is carried out in the hothouse by growing a variety of vegetable crops. In selection of the plant crops for a life-support system the following biological-technical characteristics are considered: maximum productivity per unit of hothouse space, high nutritional value, biological compatability for cultivation in closed spaces, effective use of light energy, wide temperature range for optimum growth, capability of reproduction under conditions of a space object and certain other factors. The following crops most completely satisfy the stated requirements; various varieties of cabbage (white, kohlrabi, Chinese), lettuce, table beet, dock, spinach, turnip, parsley, carrot and others.

Breeding of animal food products is carried out in a chicken cultivator. Its productivity enables us to provide the members of the crew with chicken meat and eggs in the necessary amounts.

For illumination of plants in the mockup of the life-support system we used a specially manufactured sun simulator, whose spectral distribution of radiant energy was analogous to the spectral distribution of radiant energy from the Sun in the physiologically active radiation range (Figure 2).

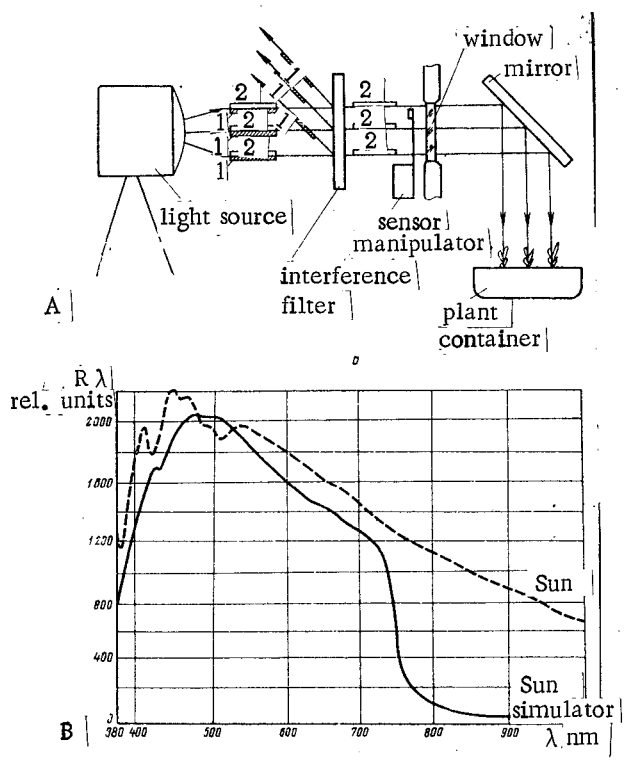


Figure 2. Circuit of the Sun Simulator  
A - Sun Simulator, B - Spectral distribution of energy of the Sun and the sun simulator.  
Key: 1 - infrared, 2 - physiologically active radiation.

The simulator consists of a projector with a high-intensity carbon lamp, in which a significant part of the emission is comprised of infrared radiation with long waves of more than 750 nm, which exerts a basically harmful heating effect on the plants. To eliminate the infrared radiation a heat filter is used which consists of water-resistant interference light filters, irrigated with circulating water. /6

The radiation from the sun simulator is fed into the hothouse through windows made of heat-resistant glass and is distributed among the plant compartments with the aid of mirrors.

The excess of heat energy and air moisture is removed by aid of the heat and moisture control system which consists of a cooling unit mounted in the hothouse, a cooling-drying unit placed in the cabin, and the heat exchanger and condenser of the algae cultivator.

Collection of liquid and solid waste products in the system is accomplished in the following manner:

Urine, used water, and the condensate from the cooling-drying unit are collected in the storage tank and sent to the unit for preliminary treatment, and then into the vessel for the nutrient solution of the algae cultivator. The corrective salt additives enter here from a common unit for preparation and adjustment of the nutrient solution.

Solid waste products are collected and stored in a separate tank.

Food preparation is carried out using products produced in the system as well as stored food products.

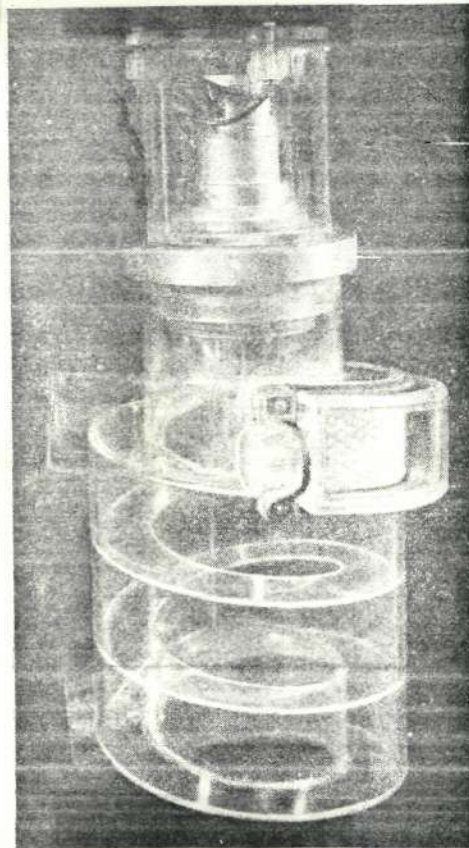
Control and regulation of the basic parameters of the gas environment in the life-support system is accomplished from the control panel. By the use of sensor units, control recording and executing devices in the cabin it is possible to maintain the following given parameters of the gas medium:

air temperature	15--50%
humidity	30--90%
partial oxygen pressure	140-300 mm Hg
partial CO <sub>2</sub> pressure	no more than 8 mm Hg.

In addition, the panel ensures maintenance of the given temperature and humidity in the hothouse and temperature of the root zone of the plants.

Automatic supply of the nutrient solution to the hothouse is carried out from the control panel, as well as collection of transpired moisture and certain other operations.

The algae cultivator has transparent containers in which a cellular suspension circulates. Its saturation by carbon dioxide is carried out in a gas-exchange apparatus (Figure 3) into which the gaseous mixture is fed by blowers from the cabin. After passing through the gas-exchange apparatus the gaseous mixture, scrubbed of carbon dioxide and saturated with oxygen, passes through the condenser-dryer and returns to the cabin. The temperature of the suspension in the circulation loop is maintained by the heat regulator in the temperature range of  $38 \pm 1^\circ\text{C}$ . The process of continuous flowing cultivation of algae is maintained by a unit for automatic maintenance of a given concentration of cells in a suspension, which consists of a density sensor, a feed-control device and a vessel for the reserve nutrient solution.



Reproduced from  
best available copy.

Figure 3. Gas Exchange Apparatus.



With an increase in concentration of cells in the suspension mentioned above, the suspension is diluted by the nutrient solution, and any excess suspension spills over into the vessel of the separator. After removal of the cells the culture medium, whose composition is adjusted in the unit for preparation of the solutions, is again used as a nutrient medium.

The volume of the cell suspension in two loops is 50 liters. The volume of the reserve nutrient solution is 8 liters. Production of oxygen is up to 1,200 liters/day.

By participation of the cultivator in the process of regeneration of water in the system its production reaches 15 liters of condensate a day.

The hothouse (Figure 4) is made in the form of a cylinder with a diameter of 3.8 meters and a volume of about 60 cubic meters, incorporating vegetation containers located on several decks with a useful area of about 20 square meters. Radiant energy is led into the hothouse through windows equipped with light filters. A system of reflectors ensures orientation of the light toward the plants on all the decks of the hothouse. Refrigeration units are used to regulate relative humidity and temperature. Operation of the heat and moisture control system is automatic. Under steady-state conditions relative humidity was maintained from 55 to 85% in the daylight period and from 60 to 90% in the nighttime period. Control of relative humidity was achieved by a psychrometric sensor and an automatic recording device. The precipitated moisture in the cooling-drying unit is sent to the transpired water collection system. The solution with a given composition and concentration produced from the transpired water is fed by a pump according to a definite program into the system for mineral nutrition of plants.

The plants in the vegetable crops for the hothouse are cultivated in special containers filled with an artificial soil substitute which holds the plants as they grow (Figure 5).

The chicken cultivator (Figures 6,7) is designed to hold a specific number of chickens, which satisfy the needs of the crew for products of animal origin.

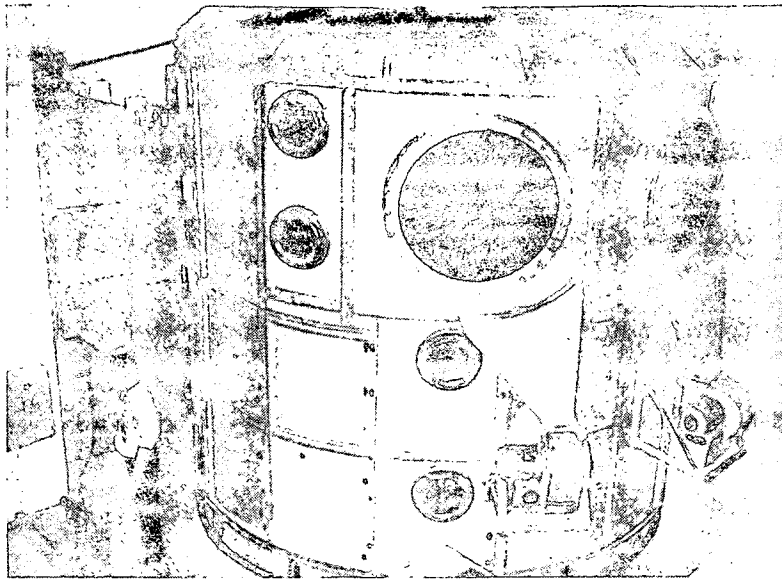


Figure 4. External View of the Hothouse.

Reproduced from  
best available copy.

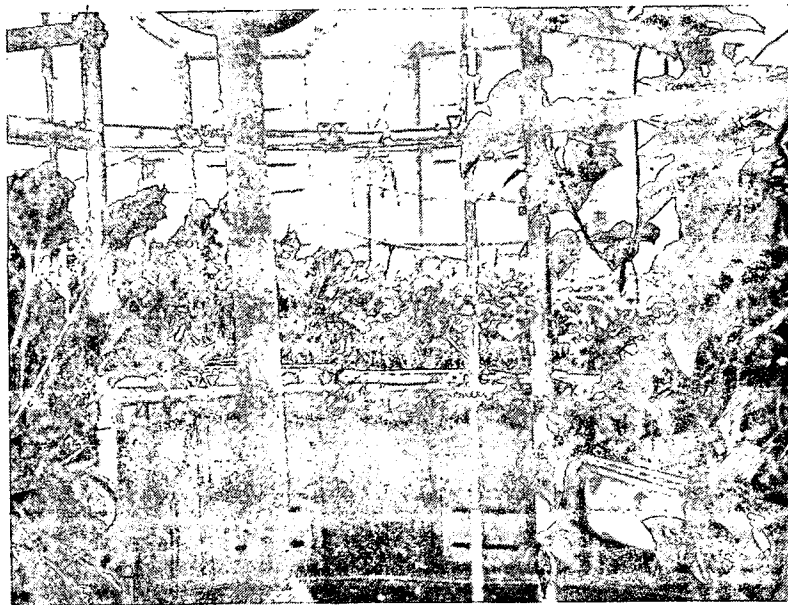


Figure 5. Internal View of the Hothouse.



Figure 6. Chicken Cultivator.

Reproduced from  
best available copy.

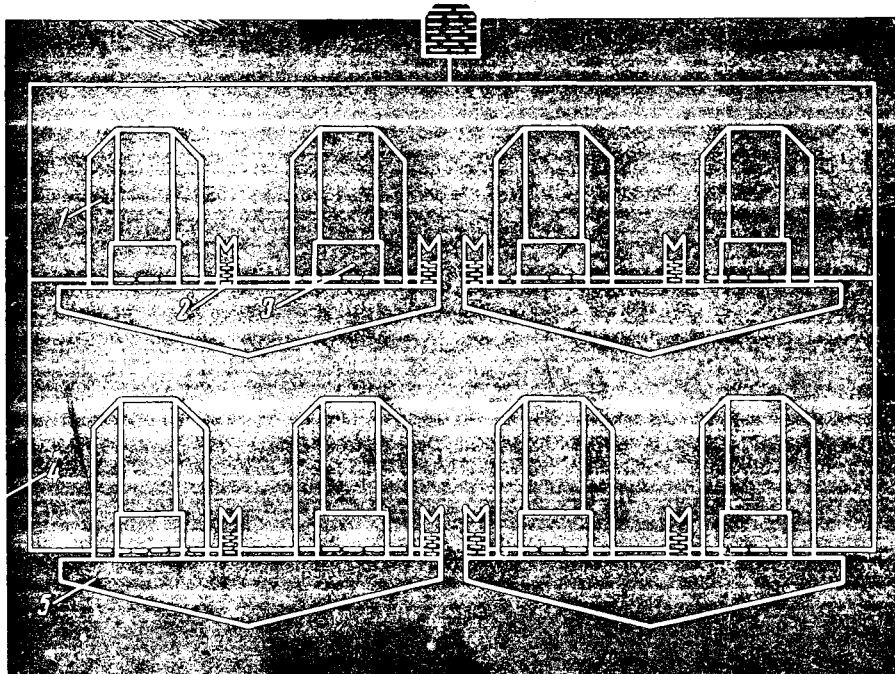


Figure 7. Flow Sheet of the Chicken Cultivator.  
1 - Compartment for holding the chickens; 2 -  
drinking bowl; 3 - feed box; 4 - housing of the  
cultivator; 5 - sanitation arrangement.

The chickens are placed in metal compartments which sharply limit their mobility. The saving of area in comparison with keeping them in cages is 40-75%.

The design of the feed boxes completely eliminates scattering of feed under conditions of weightlessness.

The drinking bowls are of a lever-type design. The chicken presses on the lever with its beak to release water into the drinking trough.

Collection of excrement is achieved by a directional stream of air which is created by the blower.

The described version of an experimental mockup of a biotechnical life-support system allows us to perfect procedures of separate components of the system, their operation in combination with other components and units of the system for the purposes of determining the maximally effective version of the system for specific conditions of a space object, and also for establishing an optimum functional and technological flow chart for the processes in the apparatus intended for operation under conditions of weightlessness.

## REFERENCES

1. Voronin, G. I. and A. I. Polivoda, *Zhizneobespecheniye Yekipazhey Kosmicheskikh Korabley* [Life-Support of Crews of Space Craft], Moscow, "Mashinostroyeniye" Press, 1967.
2. Voronin, G. I., A. I. Polivoda and V. P. Lapshin, "Modern Trends in the Development of Space and Underwater Human Life-Support Systems," in the collection: *Problemy sozdaniya zamknutykh ekologicheskikh sistem* [Problems of the Creation of Closed Ecological Systems], Moscow, "Nauka" Press, 1967.
3. Voronin, G. I. and O. N. Al'bitskaya, "Functional Peculiarities of Life-Support Systems Based on Photoautotrophic Biosynthesis," in the collection: *Materialy V rabochego soveshchaniya po voprosy krugovorota veshchestv v zamknutoy sisteme* [Data of the V Working Conference on the Problem of the Cycling of Substances in a Closed System], Kiev, "Naukova Dumka" Press, 1968.
4. Anisimov, O. L., Yu. A. Baydukin and V. F. Miskilev, "Autonomous Hothouse for Studying the Processes of Cultivation of Higher Plants," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
5. Anisimov, O. I., M. D. Borodin and T. V. Pozdneva, "Types of Light Filters and the Possibility of Using Them for Conversion of Radiant Energy During Cultivation of Autotrophs," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
6. Rodikul'tsev, Yu. V., N. N. Zadorin and V. F. Miskiley, "Device for Regenerating Air Using Photosynthesis of Algae," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
7. Milov, M. A. and G. M. Novikova, "Gas Exchange and Transpiration of Higher Plants During Growth in Artificial Conditions," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
8. Balashova, I. A., "Effect of Radiant Flux Intensity on the Effectiveness of the Use of Radiant Energy by Higher Plants," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
9. Anisimov, O. L. and I. A. Balashova, "Determination of the Optimum Relationships of Infrared and Photosynthetically Active Radiation Photoculture of Higher Plants," in the collection: *Tezisy dokladov II Vsesoyuznogo*

- soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy*  
[Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
10. Milov, M. A. and K. A. Balakireva, "Problem of the Selection of Crops of Higher Plants for a Biotechnical Life-Support System," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
  11. Skotnikova, G. S. and N. N. Zadorin, "Morphological and Physiological Changes of Chlorella Culture in Extreme Medium Conditions," in the collection: *Tezisy dokladov II Vsesoyuznogo soveshchaniya po upravlyayemomu biosintezu i biofizike populyatsiy* [Abstracts of Reports of the II All-Union Conference on Controlled Biosynthesis and Biophysics of Populations], Krasnoyarsk, 1969.
  12. *Kosmicheskaya biologiya i Meditsina* [Space Biology and Medicine], Editor V. I. Yazdovskiy, Moscow, "Nauka" Press, 1966.
  13. Rayko, A. P., O. N. Al'bitskaya and O. L. Shmelev-Shampanov, "Effect of Repeated Recirculation of a Nutrient Solution on Bacterial Contamination and Productiveness of Photosynthesis of a Culture of Unicellular Algae," *Zh. Obshch. biol.*, Vol. 29, No. 6, 1968.
  14. Al'bitskaya, O. N. and V. G. Maslennikova, "Study of the Effectiveness of a Chlorella Culture as a Filter for Absorption of Toxic Gaseous Substances Eliminated by Man," in the collection: *Materialy V rabocheho soveshchaniya po voprosy krugovorota veshchestv v zamknutoy sisteme* [Data of the V Working Conference on the Problem of Cycling of Substances in a Closed System], Kiev, "Naukova Dumka" Press, 1968.

Translated for the National Aeronautics and Space Administration under contract No. NASw-2037 by Techtran Corporation, P. O. Box 729, Glen Burnie, Maryland, 21061, translator: George C. Edwards.